

masses of tellurium and iodine, &c., are further evidences of this. The properties of tellurium and iodine may have nothing whatever to do with each other. They are, however, closely related to, and in correct order with, those of the elements of their respective groups as given above. The genesis was not in the direction of tellurium to iodine, but from, or perhaps through, oxygen and fluorine respectively. So also with regard to the other groups.

It is more probable that in the genesis of the elements the properties of certain fundamental substances are modified by successive additions of matter to them,* or by causes of which this is, to us, the apparent result. The regularity in the changes in the properties of lithium, beryllium, boron, and carbon, as seen in the diagrams, is very remarkable. It is, furthermore, very suggestive, for the changes in properties are approximately proportional to the quantity of matter in the atom in excess of a constant (which is about 6), as if it were the same matter that is added in each case.

I must express my best thanks to Dr. J. H. Vincent, to Professor Liveing, Dr. Larmor, and Professor J. J. Thomson, for the interest they have taken in this work, and for the kindly encouragement they gave me, especially in the earlier stages of it. It was while working with Professor Hartley that I acquired the knowledge of spectra which led me to begin the investigation, and I am deeply grateful to him for the means of acquiring that knowledge.

“Experimental Researches on Drawn Steel.—Part I. Magnetism and its Changes with Temperature.—Part II. Resistivity, Elasticity and Density, and the Temperature Coefficients of Resistivity and Elasticity.” By J. REGINALD ASHWORTH. Communicated by Professor SCHUSTER, F.R.S. Received January 30,—Read March 6, 1902.

(Abstract.)

PART I.

In a former paper it was shown that the variation of the intensity of magnetisation of a magnet under fluctuations of temperature is controlled to a large extent by the self-demagnetising factor of the

* *January 27, 1902.*—Professor Hartley has recently called my attention to a letter “On the Inadequacy of Aids and Facilities for Scientific Research,” which he wrote to the ‘Chemical News’ on November 9, 1895. The following statement is quoted from that letter:—“One element in a group differs in its properties from another, not because it consists of another kind of matter, but because the quantity of matter in an atom of it is different.”

magnet, the self-demagnetising factor being governed by the dimension ratio. In general, an increment of temperature in the cyclic state reduces and a fall of temperature augments the magnetic intensity, so that α in the equation

$$I_{t'} = I_t(1 + \alpha(t' - t))$$

is negative, t' being a greater temperature than t and $I_{t'}$ and I_t the corresponding magnetic intensities. But it was discovered that magnets made of pianoforte wire in the commercial state, more than 50 diameters long, exhibited a positive or incremental coefficient. If the magnet were much shorter the coefficient was decremental, and, for an intermediate dimension ratio, zero.

In the present paper a complete experimental investigation of the temperature coefficient of a magnet is undertaken. Attention is at first confined to pianoforte steel wire, and tables and curves are given of the change of α , and the change also of I , as the dimension ratio is increased from about 16 to 100 for the wire in three conditions, namely, annealed, glass hard, and commercial drawn state.

In the first two the coefficient is decremental and, in magnitude, large for annealed and very small for glass hard; but in the drawn state α changes from decremental to incremental as the dimension ratio advances. It thus appears that the drawing is responsible for the peculiar behaviour of α .

To confirm this, experiments were made on twelve samples of pianoforte steel, representing every stage in the process of drawing from the rolled rod through annealing and tempering to the fine-drawn wire, the drawing being carried one or two steps farther than is usual in commercial practice. The experiments were made on lengths of 50 and 100 diameters. The curves which are traced show very clearly that α changes in sign at a not very advanced stage in the drawing, grows more positive, reaches a maximum, and then droops towards zero again at extreme drawing. The magnetic intensity rises steadily with drawing, and shows no tendency to diminish even at the final stage of drawing; it is then about 200 per cent. greater than at the first drawing.

An examination of a piece of drawn steel wire about 400 diameters long then follows, in which susceptibility and intensity are determined when the wire was at air temperature and when it was at 100° C.

The effect of heating is very pronounced and, unlike the general behaviour of iron and steel, the hot curve of magnetisation is always above the cold curve, as the steel is carried to its greatest intensity and brought to its residual condition by the withdrawal of all force. Thus it retains more magnetism hot than cold. But on demagnetising, the hot curve droops faster than the cold curve, and the curves intersect when the reversed force is about 4 C.G.S. units, and at this

point the magnetic intensity is the same hot or cold. The explanation of the fact that a self-demagnetising force of given amount produces a zero temperature coefficient in drawn steel now becomes clear.

The influence of magnetic intensity on the magnitude of α is next investigated in a long series of observations. The wire was magnetised step by step, and at each step the temperature coefficient and the percentage permanent change of intensity were determined, both for induced and residual intensity. The temperature coefficient in general follows the susceptibility and becomes least at the highest intensity but always incremental; on demagnetising it increases slightly and then falls towards zero, which occurs at some very low residual intensity.

The behaviour of the residual magnetism as demagnetisation proceeds is very interesting; when a small part of the magnetism is removed, the effect of alternate heatings and coolings is to leave the intensity higher than before the application of heat and cold, and the more the magnetism is removed the greater the recovery by heating and cooling; and, at last, on applying so large a demagnetising force as to remove all the magnetism and to leave a small residual intensity inverse to the direction of the original intensity, then, heatings and coolings clear this out and restore some of the original magnetisation. The behaviour of the coefficient during these changes is also discussed.

For comparison, the same series of experiments was performed upon an annealed iron wire about 400 diameters long. The hot curve of magnetisation crosses the cold curve a little beyond maximum susceptibility and the maximum residual intensity is less hot than cold; it would therefore appear that at some small initial intensity the coefficient should be positive, at a later stage zero, and finally negative. The zero coefficient was not obtained in these experiments, but the subsequent negative coefficient was traced, and it was found that when the susceptibility is large the negative coefficient is a minimum; the coefficient is throughout negative during demagnetisation.

The intensity under heating and cooling is similar in behaviour to the intensity of drawn steel; on magnetising, heatings and coolings always cause a loss of residual magnetism, but on demagnetising heatings and coolings restore some of the magnetism removed. It would no doubt be advantageous for the sake of producing a magnet of constant intensity to apply a small reversed force after magnetising to saturation, any fluctuations of temperature afterwards would then tend to increase rather than diminish the intensity.

It is pointed out that the gradual decay of magnetism in observatory magnets will generally be accompanied by some change in the coefficient, and that remagnetisation of magnets will likewise alter the magnitude of the coefficient; the general effect of this change will be

determined by the position of the point of intersection of the hot and cold curves of magnetisation.

Observations, extending over several years, then follow on four magnets made of drawn steel and treated in two different ways so as to have nearly zero coefficients, and the effects of time and the effects of remagnetisation on the temperature coefficient and on the intensity are studied.

PART II.

The series of wires representing the twelve stages in the manufacture of drawn wire were subjected to examination for resistivity and its temperature coefficient, for Young's modulus and its temperature coefficient, and for density.

Resistivity is augmented by tempering but diminished by drawing up to a certain stage; extreme traction, however, causes a rapid increase again of resistivity.

The temperature coefficient is related to the resistivity, so that, in general, high resistivity and low coefficient are associated. Drawing, however, does not produce a very large change in the temperature coefficient of resistivity.

Young's modulus increases markedly with tempering and to a less extent with drawing up to the point where the resistivity is a minimum; after that, extreme drawing produces a sharp diminution of the modulus.

The temperature coefficient of Young's modulus presents an interesting relation to the modulus and like the resistivity coefficient follows in an inverse sense the modulus curve, so that when the modulus is large the coefficient is small.

It was observed that after heating and cooling the wire, the value of Young's modulus did not return to its initial value but was always a little greater; perhaps this was not a permanent effect, although it persisted for some time.

A careful series of determinations on the density of the wires showed that, with some initial irregularities, the density is very decidedly increased by drawing to the very last stage, when it becomes 8 grammes per c.cm.

There is a very close correspondence between density and magnetic intensity, the two being nearly proportional to one another over a considerable range; there is also some evidence of agreement between a smoothed curve of Young's modulus and the magnetic intensity; both appear to be functions of the density.
